(44) May 12, 1886. Attica, Fountain County, Ind. (scale 3).—Time, 10 P.M.; in vicinity, 9 killed; 200 houses razed; loss, $200,000.

(45) April 15, 1887. St. Clairsville and Martin's Ferry, Belmont County, O. (scale 3). Time, 3.20 P.M.; none killed; about 200 buildings of all kinds demolished; loss, $250,000.

(46) April 21, 1887. Prescott, Linn County, Kan. (scale 3). —Time, 5.30 P.M.; 20 killed, 237 wounded; 330 buildings razed in vicinity; loss, $150,000.

(47) April 22, 1887. Mount Carmel (near), Wabash County, Ill. (scale 3 —).—Time, 6 P.M.; 2 killed, several wounded; every thing in path destroyed; loss, $50,000.

(48) April 22, 1887. Clarksville (near), Johnson County, Ark. (scale 3).—Time, 6.30 A.M.; 20 killed, 75 to 100 injured in vicinity; loss, $150,000.

(49) June 16, 1887. Grand Forks, Grand Forks County, Dak. (scale 3).—Time, 3.22 P.M.; 4 killed; 50 or more houses, besides hundreds of barns, etc., razed; loss, $150,000.

(50) Feb. 19, 1888. Mount Vernon, Jefferson County, Ill. (scale 3+).—18 killed, 54 wounded; 100 buildings razed; loss, $400,000.

(51) May 27, 1888. Hillsboro, Hill County, Tex. (scale 3 —).—Many buildings razed; loss, $100,000.

(52) Aug. 21, 1888. Wilmington, New Castle County, Del. (scale 3).—1 killed, 20 wounded; loss $100,000 to $200,000.

(53) Jan. 9, 1889. Brooklyn, Kings County, N.Y. (scale 3).—Time, 7.40 P.M. (Eastern); width, 500-600 feet; length, 2 miles; whirl from right to left; roar heard 10 or 15 minutes before; loss, $300,000.

(54) Jan. 9, 1889. Reading, Berks County, Penn. (scale 3). —Time, 5.40 P.M.; swept from west to east in a path 60 to 100 feet wide; wind often seemed to crush from above; 40 killed; loss, $200,000 (estimated).

(55) Jan. 12, 1890. St. Louis, St. Louis County, Mo. (scale 3).—Time, 4 P.M.; moved to north-east in a path 500 to 2,000 feet wide; heavy rain for 3 minutes; greatest damage where path was narrowest; 3 killed; 100 houses razed; loss, $250,000.

(56) March 27, 1890, Metropolis, Massac County, Ill. (scale 3 —).—1 killed, 50 injured; loss, $150,000.

(57) March 27, 1890. Louisville, Jefferson County, Ky. (scale 3+).—Time, 7.57 P.M.; path at beginning 600 feet, as it left the city 1,500 feet; cloud did not quite reach the earth; great damage to property; 76 killed, 200 injured; loss, $2,250,000.

This list comprises all the most destructive storms that have been reported, as far as a definite locality was mentioned. It has been found exceedingly difficult to determine the loss in many cases, because an estimate has evidently been made of the loss to crops, orchards, etc., from the rain, hail, and floods that accompanied the tornado, and not from the wind itself. Again, the loss reported evidently referred to a large region in the county, and not to any specific town. Some of these may be enumerated as follows:—

DATE.	COUNTY.	STATE.	LOSS.
June 12, 1881	DeKalb and others.	Missouri.	$200,000
Nov. 5, 1883	Greene and others.	Missouri.	150,000
Nov. 21, 1883	Izard.	Arkansas.	300,000
April 14, 1886	Cass.	Iowa.	160,000
May 11, 1886	Pettis and others.	Missouri.	500,000
May 12, 1886	Greene and others.	Ohio.	1,000,000
May 14, 1886	Hardin and others.	Ohio.	720,000
May 14, 1886	Huron.	Ohio.	500,000
May 14, 1886	Seneca.	Ohio.	300,000
May 14, 1886	Mercer.	Ohio.	250,000

It is highly probable that in some of these cases the losses from one county have been estimated in another, though this has been avoided as much as possible. It is very much to be hoped that more definite estimates will be made in the future. The loss to structures by the wind should be carefully distinguished from the loss of every other kind, by hail or flood, and to crops, stock, or orchards. I shall be very grateful to any who will send me corrections to this list, or add other tornadoes. H. A. HAZEN.

LIGHTNING-CONDUCTORS FROM A MODERN POINT OF VIEW.[1]

A LIGHTNING-CONDUCTOR used to be regarded as a conduit or pipe for conveying electricity from a cloud to the ground. The idea was, that a certain quantity of electricity had to get to the ground somehow; that if an easy channel were opened for it the journey could be taken quietly and safely, but that if obstruction were opposed to it violence and damage would result. This being the notion of what was required, a stout copper rod, a wide-branching and deep-reaching system of roots to disperse the charge as fast as the rod conveyed it down, and a supplement of sharp points at a good elevation to tempt the discharge into this attractive thoroughfare, were the natural guaranties of complete security for every thing overshadowed by it. Carrying out the rain-water-pipe analogue, it was natural also to urge that all masses of metal about the building should be connected to the conductor, so as to be electrically drained to earth by it; and it was also natural to insist on very carefully executed joints, and on a system of testing resistance of conductor and "earth," so as to keep it as low as possible. If ever the resistance rose to 100 ohms, it was to be considered dangerous.

The problem thus seemed an easy one, needing nothing but good workmanship and common sense to make accidents impossible. Accordingly, when, in spite of all precautions, accidents still occurred; when it was found that from the best-constructed conductors flashes were apt to spit off in a senseless manner to gun-barrels and bell-ropes, and wire fences and water-butts,—it was the custom to more or less ridicule and condemn either the proprietor of the conductor, or its erector, or both, and to hint that if only something different had been done,—say, for instance, if glass insulators had not been used, or if the rod had not been stapled too tightly into the wall or if the rope had not been made of stranded wires, or if copper had been used instead of iron, or if the finials had been more sharply pointed, or if the earth-plate had been more deeply buried, or if the rainfall had not been so small, or if the testing of the conductor for resistance had been more recent, or if the wall to which the rod was fixed had been kept wet, etc.,—then the damage would not have happened. Every one of these excuses has been appealed to as an explanation

[1] By Professor Oliver J. Lodge (from Industries).

of a failure; but because the easiest thing to abuse has always been the buried earth connection, that has come in for the most frequent blame, and has been held responsible for every accident not otherwise explicable.

All this is now changing or changed. Attention is now directed, not so much to the opposing charges in cloud and earth, but to the great store of energy in the strained dielectric between. It is recognized that all this volume of energy has somehow to be dissipated, and that to do it suddenly may be by no means the safest way. Given a store of chemical energy in an illicit nitroglycerine factory, it could be dissipated in an instant by the blow of a hammer; but a sane person would prefer to cart it away piecemeal, and set it on fire in a more leisurely and less impulsive manner. So, also, with the electrical energy beneath a thunder-cloud. A rod of copper an inch or a foot thick may be too heroic a method of dealing with it; for we must remember that an electric discharge, like the recoil of a spring or the swing of a pendulum, is very apt to overshoot itself, and is by no means likely to exhaust itself in a single swing. The hastily discharged cloud (at first, suppose, positive) over-discharges itself, and becomes negative; this again discharges and over-discharges till it is positive, as at first; and so on, with gradually diminishing amplitude of swing, all executed in an extraordinarily minute fraction of a second, but with a vigor and wave-producing energy which are astonishing: for these great electrical surgings, occurring in a medium endowed with the properties of the ether, are not limited to the rod or ostensible conduit. The disturbance spreads in all directions with the speed of light; and every conducting body in the neighborhood, whether joined to the conductor or not, experiences induced electrical surgings to what may easily be a dangerous extent: for not only is there imminent danger of flashes spitting off from such bodies for no obvious reason, — splashes which, on the drain-pipe theory, are absolutely incredible; flashes sometimes from a perfectly insulated, sometimes from a perfectly earthed, piece of metal, — but, besides this, remember that near any considerable assemblage of modern dwellings there exists an extensive metallic ramification in the gas pipes, that these are in places eminently fusible, and that the substance they contain is readily combustible.

On the drain-pipe theory, the gas-pipes, being perfectly earthed, would be regarded as entirely safe so long as they were able to convey the current flowing along them without melting; but, on the modern theory, gas-pipes constitute a widely spreading system of conductors, able to propagate disturbance under ground to considerable distances, and very liable to have some weak and inflammable spot at places where they are crossed by bell-wires, or water pipes, or any other metallic ramification.

Above ground we have electrical waves transmitted by the ether, and exciting surgings throughout a neighborhood by inductive resonance. Below ground we have electrical pulses conveyed along conductors, leaking to earth as they go, but retaining energy sufficient to ignite gas, whenever conditions are favorable, at considerable distances.

The problem of protection, therefore, ceases to be an easy one, and violent flashes are to be dreaded, no matter how good the conducting-path open to them. In fact, the very ease of the conducting-path, by prolonging the period of dissipation of energy, tends to assist the violence of the dangerous oscillations. The drain-pipe theory, and the practical aphorisms to which it has given rise, would serve well enough if lightning were a fairly long-continued current of millions of ampères urged by a few hundred volts, or if there were no such thing as electro-magnetic inertia; but seeing that the inverse proportion between ampères and volts better corresponds to fact, and seeing that the existence of electro-magnetic inertia is emphasized by multitudes of familiar experiments, the drain-pipe theory breaks down hopelessly, and only a few of its aphorisms manage to survive it.

What, then, are we to set up in place of this shattered idol? First of all, we can recognize what was virtually suggested by Clerk Maxwell, — that the inside of any given enclosure, such as a powder-magazine or dynamite-factory, can, if desired, be absolutely protected from internal sparking by enclosing it in a metallic cage or sheath, through which no conductor of any kind is allowed to pass without being thoroughly connected to it. The clear recognition of the exact, and not approximate, truth of this statement is a decided step in advance, and ought to be satisfactory to those who have to superintend the practical protection of places sufficiently dangerous, or otherwise important, to make the aiming at absolute security worth while. Similarly, for wire-covered ocean-cables absolute protection is possible; but not for ordinary buildings, any more than for ordinary land telegraph-offices, is such a plan likely to be adopted in its entirety. Some approximation to the cage system can be applied to ordinary buildings in the form of wires along all its prominent portions; and such a plan I have suggested, and I understand it is being carried out, for the entrance towers and part of the main body of the present Edinburgh electrical exhibition, Mr. A. R. Bennett having asked me to recommend a plan to the committee as a sort of exhibit. For chimneys a set of four galvanized iron wires, joined by hoops at occasional intervals, and each provided with a fair earth, seems a satisfactory method; but it is to be noted that a column of hot air constitutes a surprisingly easy path, and that it is well to intercept a flash on its way down the gases of a chimney by a copper hoop or pair of hoops over its mouth. Mr. Goolden tells me that he has just applied this method to a new chimney at his works in the Harrow Road. For ordinary houses, a wire down each corner and along the gables is as much as can be expected. At many places even this will not be done. A couple of vertical wires from the highest chimney-stacks on opposite sides must be held better than nothing or than only one.

Earths will be made, but probably they will be simple ones, entailing no great expense. A deep, damp hole for each conductor, with the wire led into it, and twisted round an old harrow or a load of coke, may be held sufficient. And as to terminals, rudely sharpened projections as numerous as is liked may be arranged along ridges and chimney-stacks; but I have at present no great faith in the effective discharging-power of a few points, and should not be disposed to urge any considerable expense in erecting or maintaining them. Crowns of points on chimneys and steeples are certainly desirable, to ward off, as far as they can, the chance of a discharge; but a multitude of rude iron ones will be more effective than a few highly sharpened platinum cones. I find that points do not discharge much till they begin to fizz and audibly spit; and, when the tension is high enough for this, blunt and rough terminals are nearly as efficient as the finest needle-points. The latter, indeed, begin to act at comparatively low potentials; but the amount of electricity they can get rid of at such potentials is surprisingly trivial, and of no moment whatever when dealing with a thunder-cloud.

But the main change I look for in the direction of cheapness and greater universality of protection is in the size and material of the conducting-rod itself. No longer will it be thought necessary to use a great thick conductor of inappreciable resistance: it will be perceived that very moderate thickness suffices to prevent fusion by simple current strength, and that excessive conducting-power is useless.

In the days when the laws of common "divided circuits" were supposed to govern these matters, the lightning-rod had to be of highly conducting copper, and of such dimensions that no other path to earth could hope to compete against it. But now it is known that low resistance is no particular advantage: it is not a question of resistance. The path of a flash is a question of impedance; and the impedance of a conductor to these sudden rushes depends very little on cross-section, and scarcely at all on material. A thin iron wire is nearly as good as a thick copper rod; and its extra resistance has actually an advantage in this respect, that it dissipates some of the energy, and tends to damp out the vibrations sooner. Owing to this cause, a side-flash from a thin iron wire is actually less likely to occur than from a stout copper rod.

The only limit is reached when the heat generated by the current fuses the wire, or runs the risk of fusing it; but, in so far as oscillations are prevented, the mean square of current strength on which its heating-power depends is diminished. Accordingly, a fairly thick iron wire runs no great risk of being melted. Its outer skin may, indeed, be considerably heated; for these sudden

currents keep entirely to the outer skin, penetrating only a fraction of a millimetre into iron, and they make this skin intensely hot. But the central core keeps cool until conduction has time to act; and consequently, unless the wire is so thin as to be bodily deflagrated by the discharge, its continuity is not likely to be interrupted. Thickness of wire is thus more needed in order to resist ordinary deterioration by chemical processes of the atmosphere than for any other reason.

But the liability to intense heating of the outer skin should not be forgotten, and care should be taken not to take the wire past readily inflammable substances for that reason. For instance: it would be madness to depend on Harris's notion that a lightning-conductor through a barrel of gunpowder was perfectly safe, especially if said conductor were an iron wire or rod.

In the old days a lightning-conductor of one or two hundred ohms resistance was considered dangerously obstructive, but the impedance really offered by the best conductor that ever was made to these sudden currents is much more like 1,000 ohms. A column of copper a foot thick may easily offer this obstruction, and the resistance of any reasonably good earth connection becomes negligible by comparison. A mere wire of copper or iron has an impedance not greatly more than a thick rod, and the difference between the impedance of copper and iron is not worth noticing.

But although, in respect of obstructing a flash, copper and iron and all other metals are on an approximate equality, it is far otherwise with their resistances, on which their powers of dissipating energy into heat depend. It is generally supposed that iron resists seven times more than copper of equal section, and so it does steady currents; but to these sudden flashes its resistance is often a hundred times as great as copper, by reason of its magnetic properties. This statement is quite reconcilable with the previous statement, that in the matter of total obstruction there is very little to choose between them: the apparent paradox is explicable by the knowledge that rapidly varying currents are conveyed by the outer skin only of their conductor, and that the outer skin available in the case of magnetic metals is much thinner than in the case of non magnetic.

Questions about shape of cross-section are rather barren. Thin tape is electrically better than round rod, but better than either is a bundle of detached and well-separated wires (for instance, a set of four, one down each cardinal point of a chimney); but it is easy to overestimate the advantage of large surface as opposed to solid contents of a conductor. The problem is not a purely electrical one: it is rather mixed. The central portion or core of a solid rod is electrically neutral, but chemically and thermally and mechanically it may be very efficient. It confers permanence and strength; and the more electrically neutral it is, the less likely is it to be melted. Its skin may be gradually rusted and dissolved off, or it may be suddenly blistered off by a flash; but the tenacity of the cool and solid interior holds the thing together, and enables it to withstand many flashes more. Very thin ribbon or multiple wire, though electrically meritorious, is deficient in these commonplace advantages.

There were two functions attributed to high conducting-power in the old days, — first, the overpowering of all other paths to earth; second, the avoidance of destruction by heat. The first we have seen to be fallacious: on the second a few more explanations can be made. In so far as fusion by simple current strength is the thing dreaded, it must be noticed that a good conductor has no great advantage over a bad conductor. It is a thing known to junior classes, that, when a given current has to be conveyed, less heat is developed in a good conductor, but that, when an electromotive force is the given magnitude, less heat is developed in a bad conductor. The lightning problem is neither of these, but it has quite as much relationship to the second as to the first. There is a given store of energy to be got rid of, and accordingly the heat ultimately generated is a fixed quantity. But the rise of temperature caused by that heat will be less in proportion as the production of it is slow; and though by sudden discharge a quantity of the energy can be made to take the radiant form, and spread itself a great distance before final conversion into heat, instead of concentrating itself on the conductor, yet this cannot be thought an advantage, for, just as in the old days a lightning-rod was expected to protect the neighborhood at its own expense by conveying the whole of a given charge to earth, so now it must be expected to concentrate energy as far as possible on itself, and reduce it to a quiet thermal form at once, instead of, by defect of resistance and over-violent radiation, insisting on every other metallic mass in its neighborhood taking part in the dissipation of energy.

The fact that an iron wire, such as No. 5 or even No. 8 B. W. G., is electrically sufficient for all ordinary flashes, and that resistance is not a thing to be objected to, renders a reasonable amount of protection for a dwelling-house much cheaper than it was when a half-inch copper rod or tape was thought necessary.

A recognition of all the dangers to which a struck neighborhood is liable, doubtless prevents our feeling of confidence from being absolute in any simple system of dwelling-house protection; but at the same time an amount of protection superior to what has been in reality supplied in the past is attainable now at a far less outlay, while for an expenditure comparable in amount to that at present bestowed, but quite otherwise distributed, a very adequate system of conductors can be erected.

Only one difficulty do I see. In coal-burning towns galvanized iron wire is, I fear, not very durable, and renewal expenditure is always unpleasant. It is quite possible that some alloy or coating able to avoid this objection will be forthcoming, now that inventors may know that the problem is a chemical one, and that high conductivity is unnecessary.

NOTES AND NEWS.

THE seventh annual meeting of the Association of Official Agricultural Chemists, by a vote of a majority of the executive committee, is called to meet in Washington, in the lecture-room of the National Museum, at 10 A.M., on the 28th of August proximo.

— Professor R. S. Woodward, for many years chief geographer of the United States Geological Survey, has been appointed assistant in the Coast and Geodetic Survey. Professor Woodward was for ten years assistant engineer on the United States Lake Survey, and was assistant astronomer of the United States Transit of Venus Commission previous to his connection with the Geological Survey. He was chairman of the Section of Mathematics and Astronomy of the American Association for the Advancement of Science in 1889, and is widely known for his investigations in mathematics, astronomy, and physics. His appointment to the Coast and Geodetic Survey is a subject for congratulation on both sides.

— Records have been received, at the office of the United States Coast and Geodetic Survey, of observations made during the last cruise of the "Pensacola." The stations include the West Coast of Africa, and some islands in the North and South Atlantic. The work was done by an officer of the survey, Assistant E. D. Preston, aided by members of the ship's company. Gravity and magnetic measures were made at St. Paul de Loanda (Angola), Cape of Good Hope, St. Helena, Ascension, Barbadoes, and Bermuda. In addition, magnetic observations alone were made at the Azores (Fayal), Cape Verde Islands (Porto Grande), Sierra Leone (Freetown), Gold Coast (Elmina), and in Angola at Cabiri. The pendulums used in the gravity work were the ones employed in 1883 in Polynesia, and in 1887 at the summit of Haleakala and other stations in the Hawaiian Islands. The computations are now under way at the office in Washington.

— Mr. Ward McAllister called at the office of the Cassell Publishing Company, New York, the day before he left New York for his farm at Newport, and delivered the manuscript of his book, "Society as I have found it," into the hands of the president of the company. Since he decided to write the book, Mr. McAllister has worked on it every day, and only completed it in time to leave town before the Fourth of July. A glance at the manuscript shows that it will more than fulfil the expectations of the public. No more interesting volume of its kind has been written since